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MASTER THESIS

TITLE: Feasibility study of the new Bluetooth 5.1 location functions and the development of a business plan based on the application of this technology as a form of indoor positioning.

MASTER DEGREE: Master's degree in Applied Telecommunications and Engineering Management (MASTEAM)

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DATE: October, 6th 2020

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Abstract

The objective of this final Master's thesis is to carry out a feasibility study, both at a technical and commercial level, of the new Bluetooth Direction Finding technology based on the novelties provided by the Bluetooth 5.1 version.

The specifications of the Bluetooth 5.1 version improve location services with a direction finding feature that makes it possible to detect the direction of a Bluetooth signal.

Using this new function, the idea of the project is to make a study of this function at the technical level and in addition to developing a possible business plan based on this technology with the idea of indoor positioning or even item finding. Including a study of the ecosystem of competent RTLS systems implemented in the market at the national level.

In addition to doing a review of the state of the art of IoT and in particular of RTLS technologies and the evolution that this can bring to current logistics. Taking into account that logistics is a key area in the Industry 4.0 environment and that the application of an RTLS system on it can result in an optimization of processes and time.

I would like to thank all the people who have offered me their support during this project in a time as difficult as the one lived during this Covid-19 pandemic. But above all, my family and Yaiza, without whom this could not have gone ahead.

CONTENTS

INTRODUCTION

In modern times, technology is an essential part of the development of society and industry. And it is in this eagerness to evolve where the idea of the Internet of Things (IoT) arises which offers a large number of new opportunities for accessing data and services. The IoT revolution connects millions of different devices and services, creating an innumerable number of new applications in different fields such as: industry, health, smart homes, etc.

One of the most cutting-edge wireless technologies in the field of IoT is Bluetooth, which became a much more interesting technology from the Bluetooth 4.0 standard, which was renamed Bluetooth Low Energy (BLE). This standard has certain advantages such as a reduced chipset size, an acceptable range and a very low power consumption compared to previous standards, which allows a longer useful life for the devices. And it is with the latest version of the Bluetooth 5.1 standard, where the basic concept of this project appears. Bluetooth 5.1 brings new "direction-finding" features that will let Bluetooth devices pinpoint physical location to the centimeter, aiding in indoor positioning.

The general objective is to carry out a study on a technical level of this new location function, in addition to a study on the technical and commercial feasibility for the creation of an indoor location system based on this technology and aimed at its possible use in the logistics of Industry 4.0.

The concept of Industry 4.0 refers to the fourth industrial revolution which integrates the technologies of the third industrial revolution along with new elements that allow information processing. Those components are basically: Cyber-physical systems, Internet of Things, Big Data and Cognitive computing.

Industry 4.0 requires a change in logistics to continue advancing. Industry and logistics are closely linked, so the transformation of one without the evolution of the other is not understood. Logistics encompasses all the processes related to the coordination, movement and storage of material, equipment, inventory and operators in a company.

Therefore, logistics 4.0 includes the digitization of any of the processes and factors mentioned, the processes and factors mentioned in order to optimize the company's resources from a global perspective. And it is in this evolution of logistics where the objective of the project is focused, which thanks to the indoor location technology offered by Bluetooth 5.1 can precisely locate objects and process useful data for the business.

This Master's thesis is divided into the following chapters:

- Chapter 1: Objectives.
- Chapter 2: Internet of Things.
- Chapter 3: Technical concept development.
- Chapter 4: Business Model.
- Chapter 5: Conclusions.

In the first chapter the objectives of the project and its motivations are presented. During the second chapter, it seeks to recapitulate the state of the art of IoT in today's world, in order to put in context the technology that is going to be introduced in the next chapter. It is in the third chapter where the detailed explanation of the Bluetooth 5.1 technology is made, on which the development of the desired RTLS and IPS service will be based. The fourth chapter is based on the presentation of the entire business model created for the application of the service, which uses the technological idea mentioned in the previous chapters. And it is, finally, in the last chapter where the conclusions of the work are presented together with future development work, sustainability considerations and pertinent ethical considerations.

CHAPTER 1. OBJECTIVES

1.1. Objectives

The objective of this final Master thesis is to carry out a feasibility study at both a technical and commercial level, creating a business model for the implementation of an RTLS and IPS service based on the capabilities of the new version of Bluetooth 5.1. In addition to doing a review of the state of the art of IoT and in particular of RTLS technologies and the evolution that this can bring to current logistics.

In this way, the thesis would cover both the technological part for the investigation of the operation of the new version of Bluetooth 5.1, as well as the part of the business model that is also so important in this Master.

1.2. Motivations

The evolution that the world has undergone towards the massive use of the Internet and all the technologies that can be integrated into it such as IoT, Big Data, Cognitive computing, etc. Allowing access to a lot of resources and information, which managed correctly can become a technology that offers a breakthrough in the field of industry 4.0.

Nowadays, consumers demand personalized services adapted to their rhythms of life, for this reason, one of the great challenges facing Industry 4.0 is logistics. And it is this logistics that has found an attractive space with which to help companies to provide optimized responses for their clients using the technologies mentioned above.

The main motivation is to be able to contribute the use of these technologies and solutions for any type of company. So that they can integrate the processed data in their Key Performance Factors (KPI) and management systems with the industrial and operational plant, allowing them to be in control, make quick decisions and easily adapt to market needs.

CHAPTER 2. INTERNET OF THINGS

2.1. State of the art

The Internet of Things (IoT) describes the network of physical objects (things) that carry integrated sensors, software, and other technologies in order to connect and exchange data with other devices and systems over the Internet. These devices range from household objects to industrial tools.

Many researchers suggested several definitions that describe the IoT system from different perspectives, even so, the most common definition is given by the International Telecommunication Union (ITU) in 2012, which defines it as: "a global infrastructure for the information society, enabling advanced services by interconnecting (physical and virtual) things based on, existing and evolving, interoperable information and communication technologies ". [1]

Following [2] and Figure 2.1, with more than 26 billion IoT devices currently connected, the forecast, according to experts, is that by 2025 it will reach some 75 billion installed IoT devices.

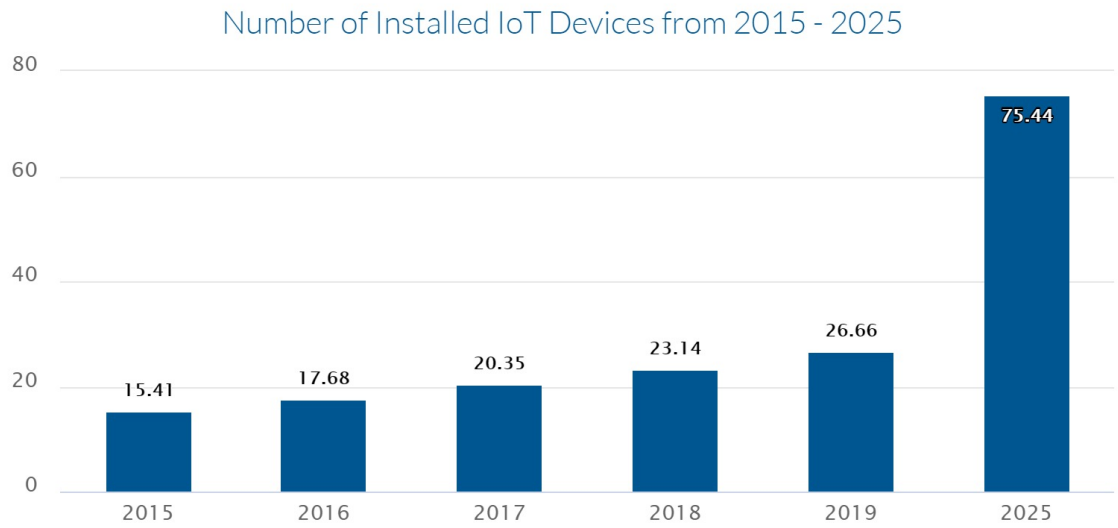

Figure 2.1: Evolution of the installation of IoT devices.

A proof of the exponential expansion that IoT technology is undergoing is the investment that has been made in it. As you can see in the following figure (Figure 2.2), the total investment in 2019 was around 230 trillion dollars. Of all this investment, around 80% is dedicated to Industry 4.0.

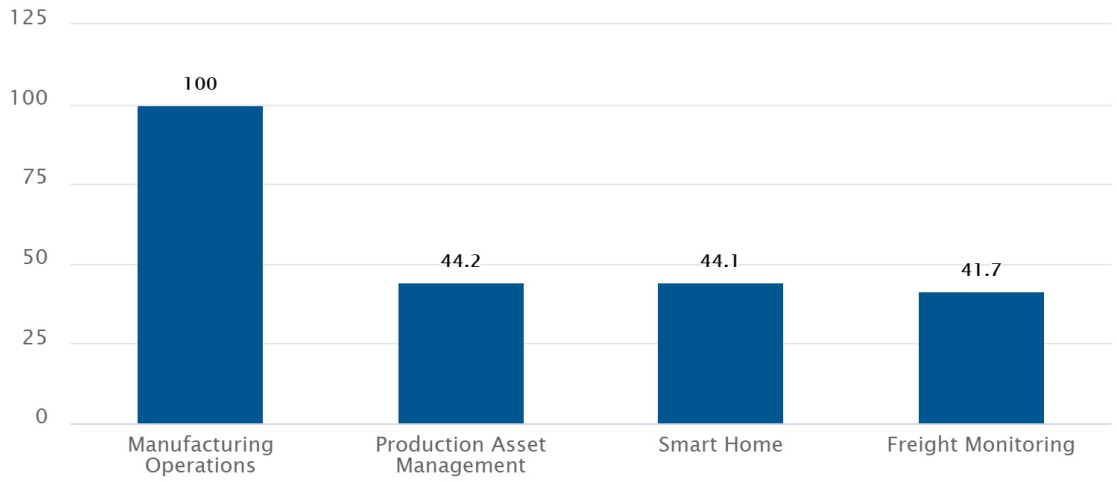

Figure 2.2: IoT Use cases with the most investment in 2019.

Although the idea of IoT technology has been developing for a long time, the latest advances made in different technologies, named below, have made it a reality:

- **Access to low-cost, low-power sensor technology:** The low cost of the sensors in both initial investment and maintenance and their high reliability make IoT technology more affordable.

- **Connectivity:** A set of transmission protocols to achieve efficient data transmission.

- **Cloud Computing, Machine learning and Big Data:** With advances in machine learning and Big Data, coupled with access to huge amounts of data from a wide variety stored in the cloud, companies can gather information faster and more easily.

2.1.1. IoT applications

The ability of IoT technology to connect a network and extract useful data on any type of everyday object allows the creation of a wide range of possible new applications in different fields as shown in the Table 2.1: [3]

Health care
Smart cities
Smart House
Industry 4.0
Connected Car
Environmental monitoring
Wearable

Table 2.1: Possible IoT applications.

2.2. Characteristics of IoT

As mentioned above, IoT is a technology that is in full growth and in constant evolution. Although this technology can be very heterogeneous, it is possible to obtain different characteristics common to all IoT technologies [3]:

- **Sensing:** Sensors are the most basic piece of this technology. Its function is to detect any type of change in any magnitude in order to generate data that reflects these changes or even interact with the environment.

- **Low power:** Most IoT devices need a minimum power consumption to have a long enough useful life.

- **Large scalability:** As mentioned in the previous section, the increase in IoT devices is billions and this creates the need to manage communication between them. In addition to managing the immense amount of data generated including useful data such as those relating to security and privacy data.

- **Complex and dynamic systems:** Performing operations between such a large numbers of devices makes the coordination of processes a very complex task due to restrictions associated with these IoT devices such as scarce memory or the need for minimum energy consumption. Furthermore, IoT is a dynamic network in which new devices are continually joining and others abandoning it. This defines the need for IoT devices to be able to adapt dynamically to any change in the network environment.

- **Self-configuring:** IoT devices can configure themselves, set up the network and are able to update their software to the latest version with minimal user intervention.

- **Heterogeneity:** The IoT environment includes different types of devices, platforms, operating systems, and services. All this must be connected to each other using different protocols.

2.3. Enabling technologies for IoT

As already mentioned in the previous sections, the IoT is a heterogeneous system in which different types of devices coexist with different types of functionalities, objectives and restrictions. That is why it is normal for different types of needs to emerge different communication protocols and standards which must be able to communicate and collaborate with each other in order to share data.

The communication protocols are the essential pieces of an IoT system since they are the ones that allow sharing the information collected by a sensor to the

network. These protocols define and specify the format of the shared data, its encoding, and its routing of packets from origin to destination.
Furthermore, the communication protocol is capable of providing other functionalities such as fluidity control or retransmission of lost packets. In the IoT environment, there are different communication protocols such as those mentioned below [3]:

- **ZigBee:** The main objective of this protocol is to establish a protocol for low energy consumption that allows training of personal area networks (PANs). ZigBee is useful for systems with type restrictions: low data rate, device with long useful life and secure networking devices.

- **Z-Wave:** Z-Wave is a protocol with a defined objective: Home automation. It is a protocol of low energy consumption and which provides a very low latency in communications with small data packet size.

- **NFC:** Near Field Communication (NFC) is a communication protocol with a very short range of action, around 4cm, which provides a simple and very secure communication between the two devices involved. The factor of security and rank has allowed its implantation in Smartphones and credit cards.

- **RFID:** RFID or Radio Frequency Identification is a remote data storage and retrieval system. Its main objective is to transmit the identity of an object, stored on a Tag, by radio frequency to the reader who will be in charge of processing the data.

- **BLE:** Bluetooth Low Energy (BLE) is a short-range communication protocol aimed at the connection between two devices and considered the key element of Wearables products. BLE is a technology available from the Bluetooth 4.0 standard, its main technical characteristics are: reduced chipset size, very low power requirements and an acceptable range in communications. Furthermore, one of the great strengths of this technology is the fact of the acceptance and compatibility obtained by large platforms such as Android, iOS, Microsoft or Linux. This technology will be studied more in depth in the next chapter of the thesis.

CHAPTER 3. TECHNICAL CONCEPT DEVELOPMENT

3.1 Bluetooth Low Energy: Specifications and features

The objective of this section is to explain in detail the new functionalities that the Bluetooth 5.1 version incorporates. Taking into account that it is this new version that allows direction finding. In order to provide consistency to the document, it is necessary to review the status of the previous Bluetooth version (BT 5.0) and in this way be able to understand and visualize more easily the improvements and updates provided by the new version. [7][8][9]

3.1.1. Bluetooth 5.0

One of the main innovations that BT 5.0 provides, and that will affect the implementation of direction finding technology, is the introduction of two new physical channels such as LE 2M PHY and LE Codec PHY.

LE 2M PHY is basically an improvement of the only channel that existed until then, LE 1M. The only change is in the modulation of data in the PHY. Using LE 2M PHY, we achieve a reduction in the energy consumed and double the transmission speed.

On the other hand, LE encoded PHY is based on encoding the payload at a lower rate of 500 Kbps or 125 Kbps, while the preamble and access address uses the LE 1M PHY rate. Using the LE Coded PHY we improve the sensitivity of the receiver which translates into an increase in the range by x2 or x4.

Regarding the range, while in the previous version of Bluetooth a range of 50m outdoor and about 10 indoor was reached, in BT 5.0 it was reached about 200m outdoor (with line of sight) and 40 meters indoor.

In addition, below (Figure 3.1) you can see the configuration of a Bluetooth package with the LE 1M or LE 2M format. Changes in this package structure will be observed in later sections in order to make the direction finding work.

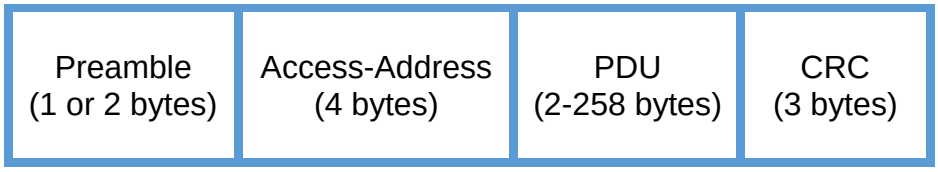

Figure 3.1: LE 1M and LE 2M Packet format.

And to finish with the Bluetooth status section it is necessary to comment that between the BT 5.0 and BT 5.1 versions, which is the one that we will detail below

since it is the one that incorporates the possibility of direction finding, there are few significant changes apart from availability of the Angle of Arrival and Angle of Departure.

3.2 Bluetooth Direction Finding

Until the launch of the Bluetooth 5.1 version, the proximity and positioning solutions offered by this technology were based on calculating the distance from the Received Signal Strength Indicator (RSSI).
The launch of Bluetooth 5.1 version brings with it a new functionality for Bluetooth devices that allows to determine the direction of a Bluetooth signal with great precision of degrees.

Direction finding, can be exploited by Bluetooth developers with the aim of creating real-time location systems (RTLS) and indoor positioning systems (IPS).

This new functionality offers two methods to determine the angle of a Bluetooth signal: angle of arrival (AoA) and angle of departure (AoD). Both methods have in common that they require, although in a different location, an array of multiple antennas. In the case of AoA in the receiving device while in the case of AoD in the transmitter.

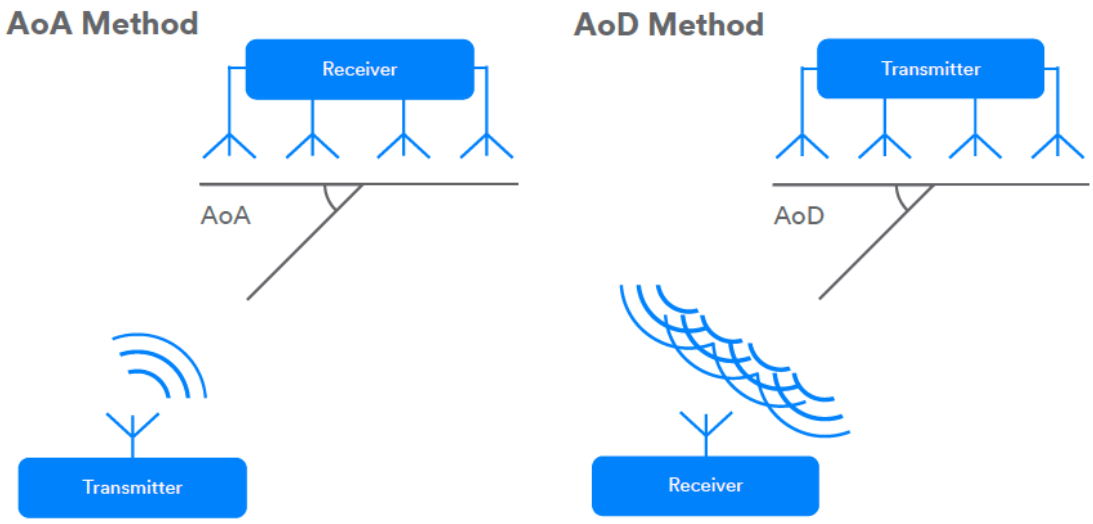

Figure 3.2: AoA Method and AoD Method.

3.2.1. Angle of Arrival and Angle of Departure

Bluetooth direction finding is based on the use of In-Phase and Quadrature (IQ) sampling to measure the phase of radio waves incident on an antenna at a specific time.

The key to calculating AoA and AoD lies in the use of the signal phase difference that exists due to the difference in distance between each antenna in the antenna array and the single transmit antenna. Then it is the positioning engine, which then uses this information about the phase difference to calculate and determine the angle of the single transmit antenna.

3.2.1.1 AoA calculus

The radio waves sent by the transmitting beacon are received by the multiple antennas in the receiver array. For each of the array antennas the received signal path is different so that information on the phase difference between each signal path can be obtained.

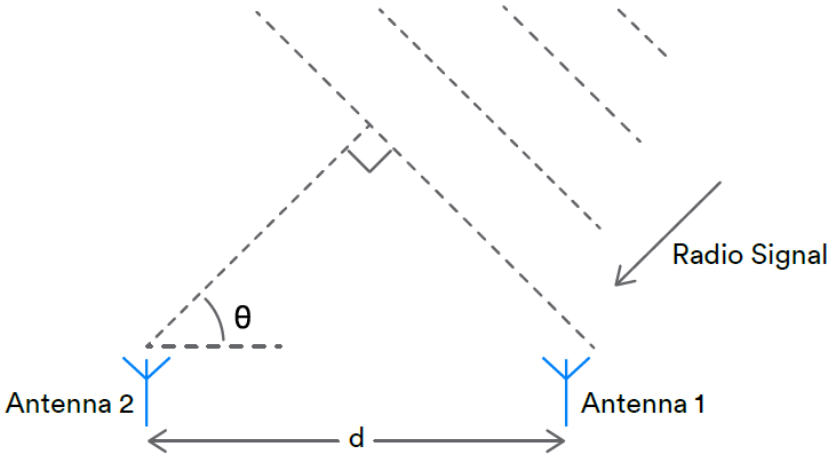

Figure 3.3: Phase difference applicate to AoA.

The equation (Eq. 1) that relates the signal phase to the phase difference is as follows:

$$\theta = \arccos\left(\frac{\phi\lambda}{2\pi d}\right)$$

Eq 1. Equation Angle of Arrival

Where:

$$\theta \equiv Signal\ phase$$

$$\lambda \equiv wavelength$$
$$\phi \equiv Phase\ difference$$
$$d \equiv distance\ between\ adjacent\ array\ antenna$$

The Bluetooth core positioning engine is in charge of using the phase difference information together with the signal phase, wavelength and distance between the array antennas to determine, using basic trigonometry and the information of all the antennas from the array, the Angle of arrival.

3.2.1.2 AoD calculus

Radio waves sent from a transmitter beacon with an array of antennas are received by the receiver's single antenna, which uses the different paths of the received signals and their different phase, due to the distance between each antenna in the transmitter array, to be able to obtain information of the phase difference.

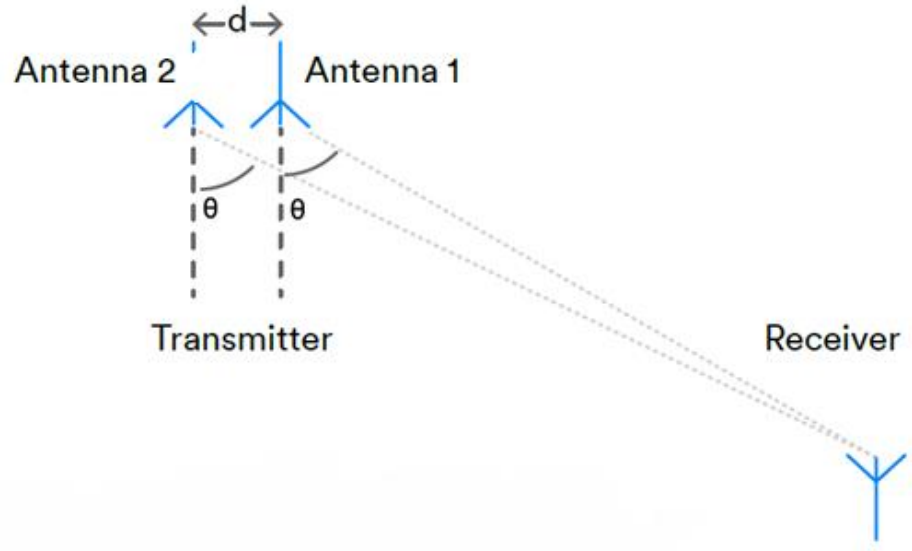

Figure 3.4: Phase difference applicate to AoD.

Unlike in the case of AoA, the AoD can be calculated directly with the following equation (Eq. 2):

$$\theta = \arcsin\left(\frac{\phi\lambda}{2\pi d}\right)$$

Eq 2. Equation AoD

Where:

$$\theta \equiv Angle\ of\ arrival$$
$$\lambda \equiv wavelength$$
$$\phi \equiv Phase\ difference$$

$$d \equiv distance\ between\ adjacent\ array\ antenna$$

3.2.1.3 Sampling

Bluetooth direction finding, in both AoA and AoD, uses signals specifically created for direction finding signals. The reception of this type of signals by a receiving device is based on the realization of amplitude and phase measurements in very precise time intervals. This sampling process is called In-phase and Quadrature sampling (IQ sampling).

An IQ sample consists of the representation as a set of Cartesian coordinates of the amplitude and angle of the phase of the sampled radio wave, as it can be seen in the image below (Figure 3.5).

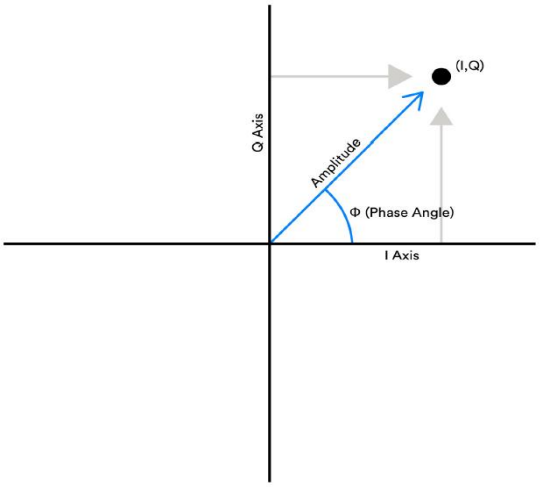

Figure 3.5: In-phase and Quadrature sample.

The way in which IQ sampling is performed in a multiple antenna device depends on the method in which it is worked, AoA or AoD. In the case of working with the AoA method, it is the receiver that contains the array of antennas and will be the one who performs an IQ sampling for each of the array antennas.

On the other hand, if we work with the AoD method, in which it is the transmitter who has the array of antennas, it is still the receiver who performs the IQ sampling. The receiver measures with its single antenna and uses the characteristics of the transmitter array design to attribute a measurement to a specific transmitter array antenna. That is why in the case of AoD, the transmitter has to communicate details of the configuration of the transmitter antenna array to the receiver.

In the image shown below (Figure 3.6), it is shown as in the AoA method, a simple transmitter emits a signal which shows a different phase upon reaching the antenna array due to the difference in distances between the antennas.

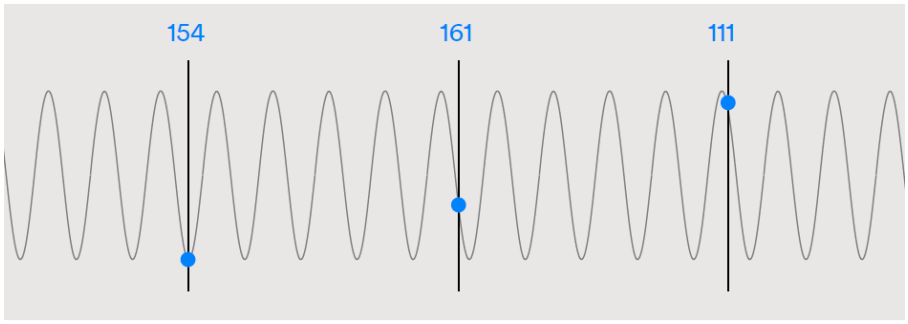

Figure 3.6: Sampling from different antennas.

3.2.1.4 Antenna Arrays

As previously discussed, the configuration of the antenna array influences the phase difference and therefore the calculation of the direction finding.

Although it will not go into much detail about the design and operation of the different types of antenna arrays, if it is necessary to mention, that the design of this for direction finding is not easy, since each of the antennas in the array influences about the behaviour of others.

An effective array design means guarantee of quality IQ sampling. There are three typical models of antenna arrays and which are well studied: uniform linear array (ULA), uniform rectangular array (URA) and uniform circular array (UCA).

- ULA: Set of antennas aligned in a straight line and equally spaced from each other. It is the simplest type to implement but it has a disadvantage with respect to URA and UCA, it is only capable of calculating the azimuth angle assuming that the object you want to locate moves in a single plane. This is because it is a one-dimensional array.

- URA: Set of antennas aligned in the shape of a rectangle and that, unlike uniform linear array, is capable of measuring both azimuth and elevation angles.

- UCA: Set of antennas aligned in a circumference and that, like UCA, is capable of measuring both azimuth and elevation angles.

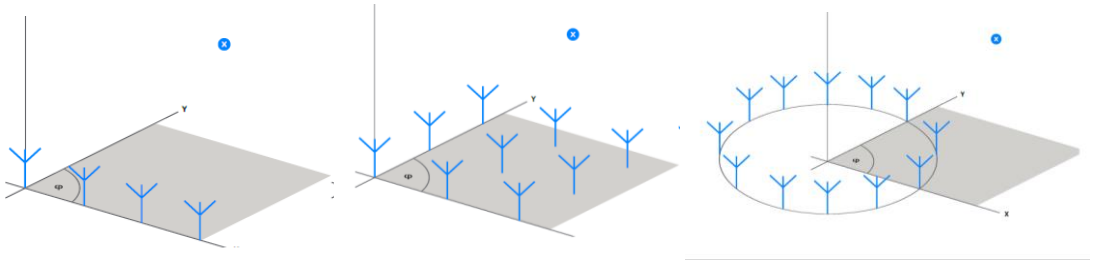

Figure 3.7: ULA, URA and UCA.

In conclusion, although all three types of antenna arrays are capable of measuring elevation and azimuth information, URA and UCA are able to offer more reliable azimuth information.

And as it can be seen in the following image (Figure 3.8), the union of the lines that form the azimuth and elevation angles serve to point the location of the device with a high precision range.

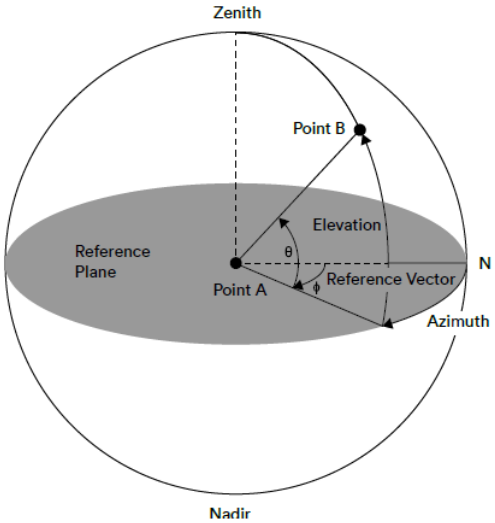

Figure 3.8: Representation of Azimuth and Elevation Angles.

3.2.2. Bluetooth direction finding signals

In order to measure IQ, the Bluetooth Core Specification, version 5.1, adds a new field to the Bluetooth link layer: Continuous Tone Extension (CTE), which allows the receiver to extract the IQ components from the RF signal received without the disruptive effects of modulation.

Furthermore, using the Host Controller Interface (HCI), it is much easier to configure the protocol controller that performs IQ sampling. This is due to HCI has also been modified so that data acquired by the controller can be made available to upper layers of the stack where direction calculations can be performed.

The purpose of the CTE field is to facilitate IQ sampling and this is accomplished by providing a constant frequency and wavelength signal. CTE is a pure tone sent to the Bluetooth carrier frequency plus 250 kHz between 16 and 160 µs. The field contains sequence of 1s, not subject to the usual whitening process, which is transmitted long enough for the receiver to extract the IQ data without the disruptive effects of modulation. Because the CTE signal is transmitted last, CTE is not included in the packet's cyclic redundancy check (CRC) calculation. Below you can see a diagram (Figure 3.9) of how the Bluetooth direction finding signals are configured, including the CTE.

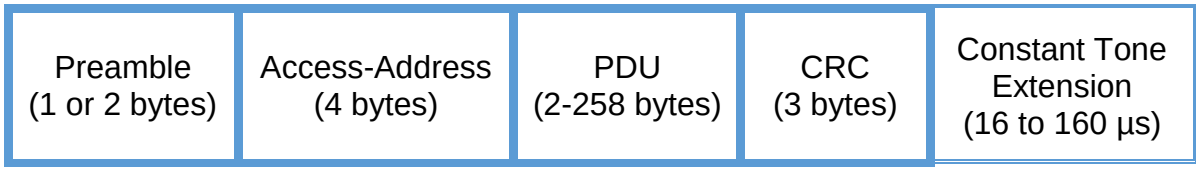

Figure 3.9: Constant Tone Extension.

3.2.3. Use of Bluetooth direction finding signals

This new section will discuss four key points which are affected by the use of Bluetooth direction finding signal, such as: The choice of the physical layer, the use of connection-oriented or connectionless, the Host Controller Interface and the timing of switching and sampling.

3.2.3.1 Choices of Physical layer

As mentioned in the previous 3.1.1 section, the Bluetooth Core Specification v5.0 introduced three different physical layers to the stack: LE 1M, LE 2M and LE Coded.

The fact of using Bluetooth direction finding signals creates a restriction in the choice of the physical layer. This restriction is that the LE Coded layer cannot be used. Therefore, a choice must be made between the physical layer LE 1M or LE 2M.

3.2.3.2 Connection-Oriented and Connectionless Direction finding

Due to the improvements introduced by the Bluetooth Core Specification 5.1 in the Bluetooth controller, it is possible to use both connection-oriented ("paired") and connectionless technology in the two types of techniques, AoA and AoD. For the AoA method, the most standardized is the use of connection-oriented applications while, conversely, for the AoD method it is more common to use connectionless applications.

The main difference between the two types of use, connection-oriented and connectionless, resides in the different application of the CTE. While in the connection-oriented type the CTE is appended to the standard packet, the connectionless type use an advertising packet.

In both methods, there are different configuration variations that must be made before starting the IQ sampling and it is the host who, through the use of the host controller interface (HCI), completes this configuration.

3.2.3.3 Host Controller Interface

The host controller interface is responsible for providing an interface through which the host is able to configure the Bluetooth controller. In the case of direction finding, it is in charge of the configuration of the generation and reception of the CTE, the configuration of which will depend if one works in connection-oriented or connectionless.

It is in the HCI configuration where, following strict timing rules, the operating pattern of the antenna switching of the antenna array and the IQ sampling performance is specified (Table 3.1).

As expected, antenna change can only occur on a device with antenna array. In the case of AoA it will be the transmitting device while in the AoD case it will be the receiving device.

On the other hand, IQ sampling is always performed at the receiver regardless of the number of antennas it contains.

	AoA		AoD	
	Switching	Sampling	Switching	Sampling
Transmitter			✓	
Receiver	✓	✓		✓

Table 3.1. Switching and sampling roles and responsibilities.

Furthermore, using the Host Controller Interface, it is much easier to configure the protocol controller that performs IQ sampling. This is due to HCI has also been modified so that data acquired by the controller can be made available to upper layers of the stack where direction calculations can be performed.

3.2.3.4 Timing of switching and sampling

The Bluetooth Core Specification v5.1 defines the time rules that govern both switching and IQ sampling when handling the CTE. The total time available for the CTE process is divided into a guard period of 4µs, a reference period of 8µs and then a sequence of switch slots, sampling slots or pairs of switches and samples slots. As expected, IQ sampling is performed during the sampling slot, while the antenna switch is performed during the switch slot.

The guard period is a resource that is used for the purpose of ensuring a gap between adjacent transmissions and thus avoiding interference between them.

The reference period is used to perform eight IQ samples in 1µs intervals from the first antenna. The host, using these 8 references samples, must be able to estimate the features of the signal such as its frequency or wavelength. Allowing in this way a more precise calculation of the angle. It is also important to mention that during this period there is no antenna switching.

Following the standards set in the Bluetooth Core Specification v5.1, sample and switch slots can be 1µs or 2µs, and it is the Host Controller Interface in charge of indicating what slot length the controller will use.

At this point it is necessary to comment on the different behaviour depending on whether it is AoA or AoD. In the case of AoA, as the CTE is received, the antenna switching occurs according to the configuration given by the HCI. However, in the case of AoD, since the CTE is transmitted, antenna switching is necessary when it is transmitted, not when it is received. Below (Figure 3.10) is an outline of how the CTE timing rules would work in the case of AoA.

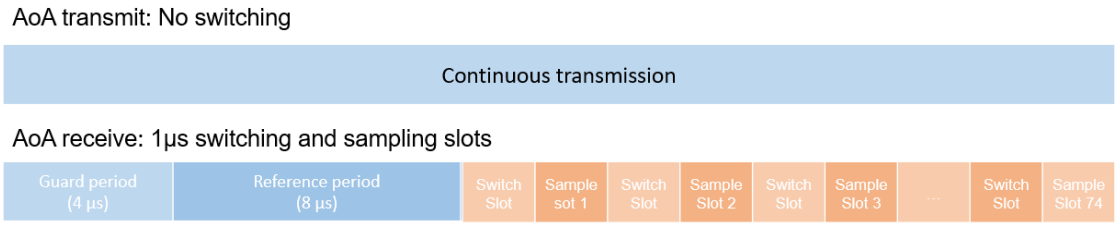

Figure 3.10: CTE timing rules AoA.

CHAPTER 4: BUSINESS MODEL

4.1 Technological idea

The technological idea behind this project is to use the direction finding capability offered by the new version of Bluetooth 5.1, which has been discussed in the previous chapter, to create a Real-Time Locating System (RTLS) and apply it to the new logistics of industry 4.0.

RTLS together with the advantages offered by AoA technology can provide data relevant to the location of operators, making logistics data relevant to operators and making the logistics process faster and smoother.

An RTLS, in addition to helping with improving productivity, is also capable of improving decision-making in real time. Another factor point in which the RTLS can influence is in the possible identification of hidden costs of the system.

Furthermore, using AoA technology, it is possible to determine the position or direction of movement of a person or object. This is a very important point for applications such as access control, tracking or monitoring of people or objects and avoidance of collisions.

Indoor object tracking is of great importance in both industry and logistics 4.0 due to three very important factors:

- Time saving.
- Optimization of processes.
- Protection against theft.

Once the position of the tracked object is calculated thanks to the Bluetooth direction finding system, it can be linked, as will be explained later, to the company's ERP system. And in this way, manage any type of production or distribution operation in a more efficient way.

The problem that this project seeks to solve is inefficient warehouse operations, which are associated with unnecessary delays or the appearance of extra costs. One of these inefficient operations is the necessary search time used by warehouse workers to find an item, this time slows down the process and reduces labour productivity.

As an example of this increase in efficiency, the company Procat Distribution Technologies [28], which has helped hundreds of distribution centres in the United States to improve productivity and precision with hands-free barcode reading technology. The company has carried out a study in which it is shown how the increase in the productivity of the benefits is 20%, this is because the use of technology affects the efficiency of the workers' work. And it is thanks to this great increase in productivity between a classic warehouse and a 4.0

warehouse that it is worth the investment in modernizing it. In the following reference you can see the figures of the complete study. [29]

Another aspect of the problem is the tracing and monitoring of employees or objects such as a forklift or a pallet. This monitoring can be useful from an optimization point of view but also for security reasons.

The image that can be seen below (Figure 4.1) shows an example of what a warehouse or a logistic centre would look like in which an RTLS based on Bluetooth direction finding is applied. As you can see, it can be tracked or located from the position of people to the position of pallets or mechanical carts. [36]

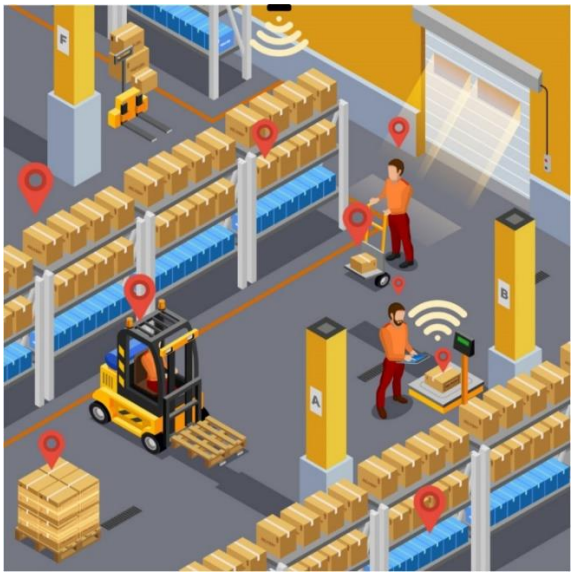

Figure 4.1: Logistic centre with RTLS applied example.

The operation of a system like the one in the previous figure (Figure 4.1) would work in the following way showed in the next scheme (Figure 4.2): Throughout the warehouse or logistics centre there are distributed BLE 5.1 labels which emit the signal that is collected by the array of antennas of the locator (use of the AoA technique). This receiver, which is capable of calculating the position of the object, is connected via Wi-Fi or Ethernet with the server and it is the latter that processes the information and transmitted to the company's ERP system.

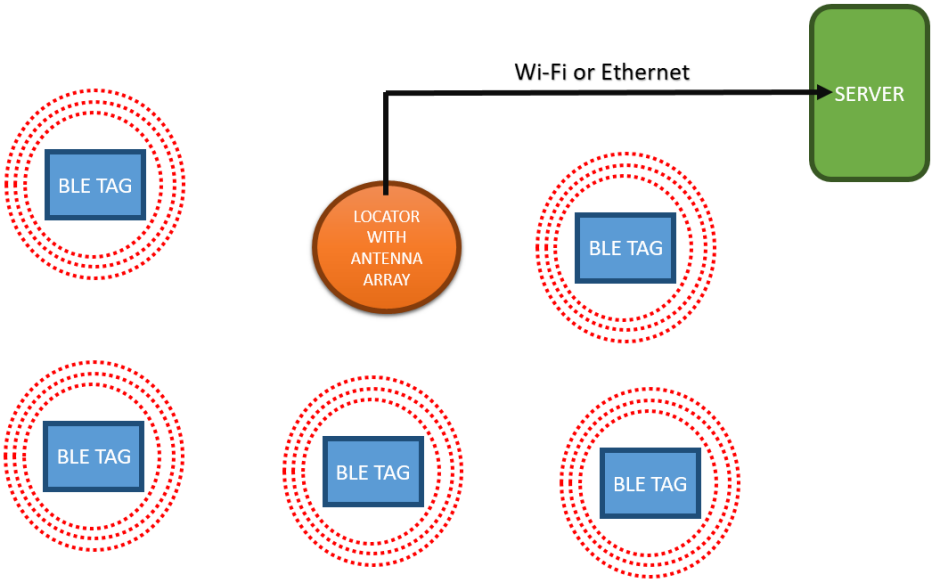

Figure 4.2: Operation of System RTLS with BLE 5.1 technology.

In addition to all this, the system can incorporate sensors for temperature, humidity, speed, etc. Providing this information that can also be useful for logistics and that can be transmitted by the same Bluetooth system.

4.1.1 Viability of the technological idea

The development of the system would be carried out with the development kit nRF5340 PDK [11] (Figure 4.3). The nRF5340 PDK is the preview development kit for the nRF5340 SoC.

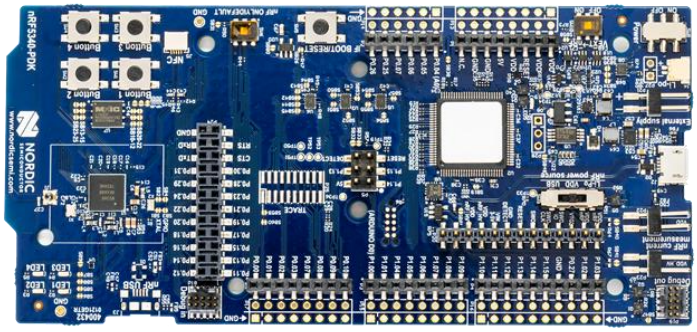

Figure 4.3: nRF5340 PDK

The system on a Chip (SoC) that would be used for the implantation of the system would be nRF5340 [10]. The nRF5340 (Figure 4.4) is an all-in-one SoC that supports an extensive range of wireless protocols. It supports Bluetooth Low Energy, and is capable of all AoA and AoD roles in Bluetooth Direction Finding,

in addition Bluetooth Long Range and 2 Mbps. The complete specifications of the device can be seen in the link of the reference.

Figure 4.4: nRF5340 SoC.

Both the development kit and the SoC are manufactured by the Nordic Semiconductor company. Below is the sale price of SoC product at the Spanish distributor that is Mouser electronics (Table 4.1).

Quantity	Unit Price	Total Price
1	8,09 €	8,09 €
10	7,43 €	74,30 €
25	6,75 €	168,75 €
100	6,07 €	607,00 €
250	5,56 €	1.390,00 €
500	5,06 €	2.530,00 €
1.000	4,55 €	4.550,00 €
2.500	4,39 €	10.975,00 €

Table 4.1: Pricing of nRF5340 SoC.

As it may seem logical, the more you buy the lower the price per unit. Coming to be a difference of 3.7 € in the unit price in accordance with the purchase volume.

4.1.1.1 System feasibility

Throughout the development of the project, and once the theoretical knowledge of the operation of the Bluetooth Direction Finding technology was acquired, an attempt was made to carry out a practical demonstration of the technology and the service that was to be offered.

For this demonstration, the aforementioned nRF5340 PDK Development Kit was purchased. Due to the global crisis caused by Covid-19, the arrival of the kit was delayed up to almost two months, which was the first inconvenience.

Once the kit was received, I started working with it, researching its workings and reading tutorials from the supplier itself. Although none of these tutorials was

related to direction finding, and what's more, there was no reference to it on their website for developers.

It is the provider itself who offers a development software called nRF Connect SDK (Figure 4.5). The nRF Connect SDK offers developers an extensible framework for building very small applications in highly constrained circumstances. For the specific case of our nRF5340 development kit, the nRF Connect SDK contains all the necessary software, including protocol stacks. [31]

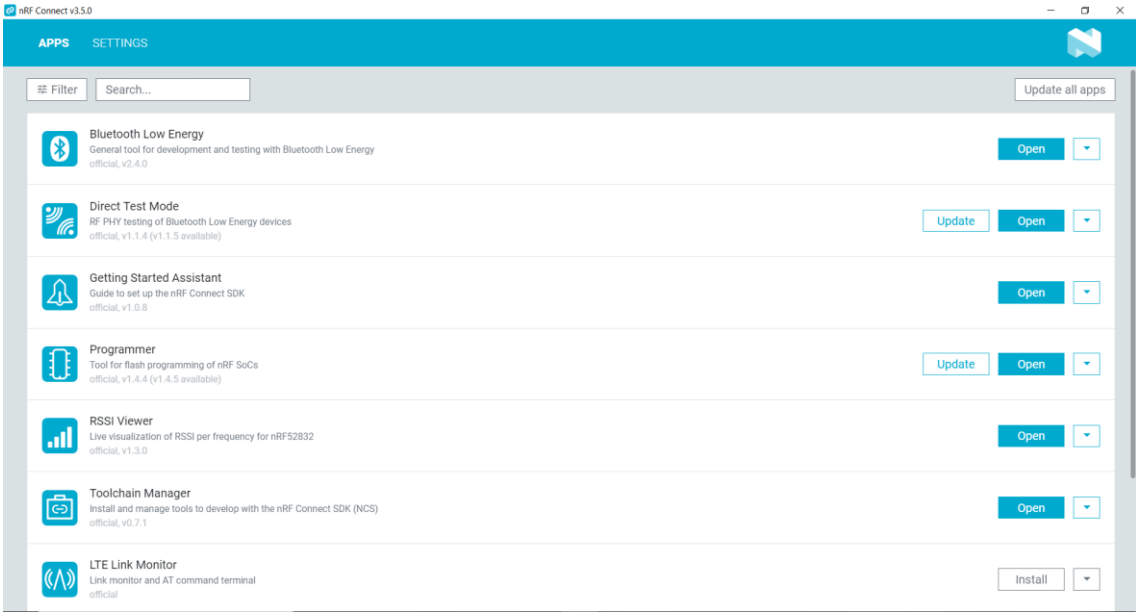

Figure 4.5: nRF Connect SDK for Desktop.

Once this difficulty was assumed and after much research, I realized that this development kit was not complete, but lacked the necessary antenna array for reception. That is, the kit only had the chip with Bluetooth 5.1, which means that it could perform the calculation of the position once the Bluetooth signals were received, but these could not be received by the chip itself since it did not have the antenna array.

Once this was assumed, and after asking the provider about the availability of these arrays, the answer was negative and they literally said the following: "I'm sorry, but we don't have any reference design for direction-finding antenna arrays as of yet. We are currently working on a solution with a development kit + antenna array + firmware. ".

After this answer I assumed that it was not yet possible to make a demo of this technology. Therefore, the rest of the project, based on the business model, is based on the theoretical performance of the technology, since the physical demonstration has not been possible to date.

4.1.2 Current state of the market

Currently on the market there are different technologies that can be the direct competition of our indoor RTLS system based on Bluetooth direction finding, these technologies are as follows: RFID, WPS, UWB and ZigBee.

The operation of each of these technologies is detailed below, and the last subsection indicates the competitive advantages that Bluetooth direction finding has over them.

4.1.2.1 Active RFID

Radio Frequency Identification (RFID), as already discussed in Chapter 1 of this document, is one of the most popular standards used for RTLS. The fact of being active RFID indicates that the labels are equipped with small batteries to improve the signal. Its advantages are its high precision, immunity to interferences and small sensors and therefore can be easily kept out of sight. On the other hand, its cons are very short range (<1m), only providing a "point in time" location and does not provide direction of arrival.

4.1.2.2 WPS

Wi-Fi Positioning System (WPS) uses multiple Wi-Fi access points (Figure 4.6), where each one measures the relative signal strength of the assets to approximate their position within a facility. [11]

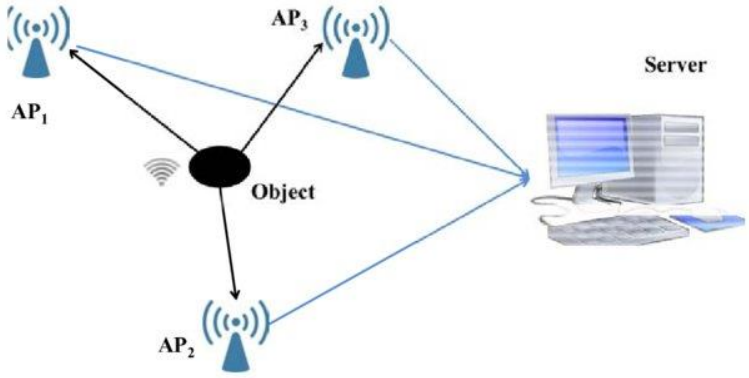

Figure 4.6: Wi-Fi Positioning System general view.

Its advantages would be the possibility of using the existing Wi-Fi infrastructure and its great range of up to 150m. Against it has its relative inaccuracy (5-15 m) compared to technologies such as BLE or RFID, the fact that it does not guarantee latency and does not offer direction of arrival either.

4.1.2.3 UWB

Ultra-wideband is a very short range wireless radio technology with very high precision. This is possible thanks to the use of a communication channel that broadcasts information over a large part of the frequency spectrum. [13]

With respect to positioning, this technology is valid for location thanks to the use of time difference of arrival (TDOA) which makes it possible to calculate the distance between the reference point (anchors) and the target. Its advantages over other technologies are its high precision and low latency. By cons, its high cost of implantation and the long useful life of the battery are weak points.

As this technology is still under development, it implies that its implementation in the market is still very slight.

4.1.3 Competitive advantages

Once discussed all the rival technologies and analyzed their pros and cons, it is time to point out the competitive advantages that Bluetooth direction finding technology has over those mentioned previously.

From a pure technological point of view there are several advantages such as low energy consumption, high precision compared to technologies such as Wi-Fi or angle of arrival availability. In addition to all this, BLE has a profitable and discreet hardware, suitable for a flexible implementation to the existing infrastructure and compatible with different development technologies such as iOS, android, etc.

Below is a comparison table (Table 4.2) where you can see the behavior of each technology depending on its precision, range and battery life.

	Accuracy	Range	Lifetime
Active RFID	< 15 cm	< 1 m	High
BLE	1-3 m	< 75 m	High
WPS	< 15 m	< 150 m	Medium
UWB	< 30 cm	< 150 m	Low

Table 4.2: Comparison of wireless technologies.

In addition to this purely technical comparison of technologies, there are other advantages that Bluetooth Low Energy technology has over UWB technology which, as will be demonstrated (4.3.5.3), is the most widely used technology in the RTLS market competition. These advantages are:

- The cost of a Bluetooth Low Energy beacon can be up to four times less than that of a UWB.

- BLE is based on Bluetooth standards unlike UWB technology which makes use of proprietary UWB protocols and custom devices.

- And as a more differential point, the fact that BLE in its version 5.1 can use AoA technology thanks to the array of antennas in the receiver / locator, allows the number of hardware (locators / anchors) to be reduced compared to other technologies and in particular UWB technology.

Below (Figure 4.7), you can see perfectly an example of how a system with the new version of BLE 5.1 can reduce the number of hardware used.

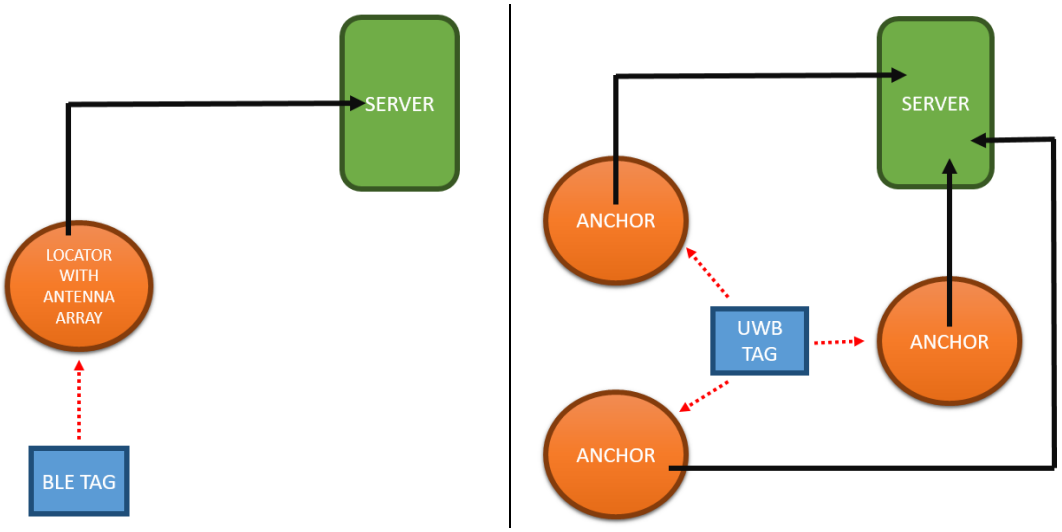

Figure 4.7: Demonstration less hardware with BLE 5.1.

4.1.4 More efficient application scenarios

As is evident, for all types of technology there are better and worse scenarios. Scenarios where the result of the service is more efficient than in other types of scenarios. And this is of greater importance when we talk about using Wireless technology such as Bluetooth Low Energy, since its efficiency will depend, basically, on the line of sight (LoS) between the transmitter and receiver.

Due to the very characteristics offered by the BLE technology in its version 5.1, it cannot compete at the level of efficiency in scenarios where the main objective is a precision of the order of centimeters, but it becomes a very precise technology in scenarios where the precision does not be such a high requirement or, on the other hand, in scenarios where the LoS is very good and can reach a very high precision.

A clear example of very beneficial scenarios for this technology would be a warehouse with wide aisles and in which the objects stored are of a relatively large size. In this way, the IPS service could give high efficiency, in addition to favoring the great competitive advantage of the technology, which is the saving of hardware since a single receiver could serve many different transmitters.

However, if we are in a warehouse scenario with very narrow aisles and very small objects, which at first do not match the precision of the technology, the LoS would be bad and would lead to an increase in the receivers necessary for a good efficiency, which would miss the strongest competitive advantage of this technology.

To give another example of a very favorable scenario for this technology would be, for example, a gym. Which consists of a single room totally open and where customers can circulate through it totally free. In this type of scenario, it would be very easy to keep track of clients around the room with a very small number of receivers.

4.1.5 Hype cycle of Bluetooth Direction Finding Technology

In this section, a study will be carried out on the Gartner's Hype Cycles through which the technology we are dealing with is passing. The description provided by Gartner, the world's leading research and advisory company, of the Hype cycle is literally the following [32]:

"The Hype Cycle is a graphical depiction of a common pattern that arises with each new technology or other innovation. Although many of Gartner's Hype Cycles focus on specific technologies or innovations, the same pattern of hype and disillusionment applies to higher-level concepts such as IT methodologies and management disciplines."

The main objective of these diagrams is to show graphically the maturity, adoption and commercial application of certain specific technologies. This Gartner Hype Cycle report is published annually and offers a broad view of trends in emerging technology industries, helping to figure out whether we are facing overexpecting or viable technology.

The Gartner Hype Cycle assesses the level of expectation over time. In addition, this is divided into 5 different areas as can be seen in the following figure (Figure 4.8) and which represent the five key phases of the life cycle of a technology [33]: innovation trigger, peak of inflated expectations, trough of disillusionment, slope of enlightenment and Plateau of productivity.

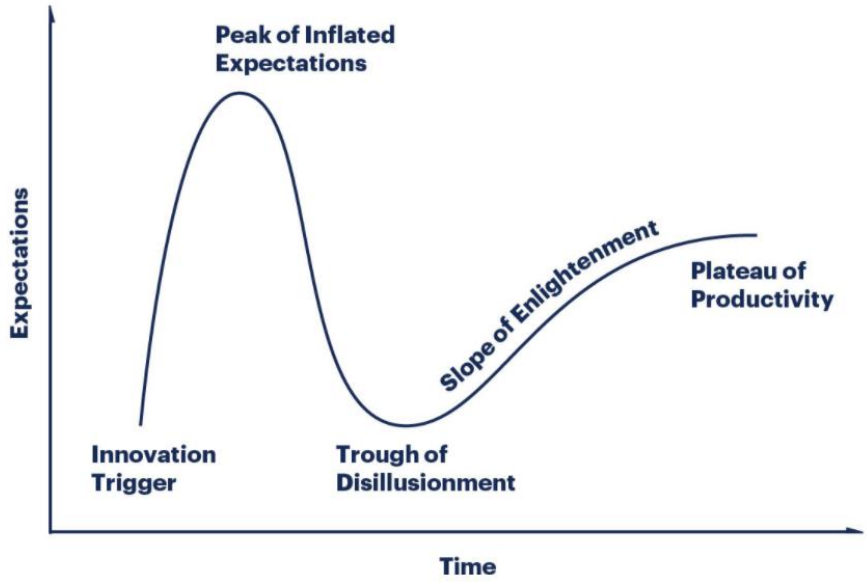

Figure 4.8: Gartner Hype Cycle's areas.

The fact that the Gartner Hype Cycle report is private and only shared with industry insiders, it is an added difficulty to have public access to the full report. That is why after an intense search on the internet, it has been possible to locate two graphs related to our project although both are from the year 2018 [34]: Hype Cycle for IoT Standards and Protocols and Hype Cycle for the Internet of things.

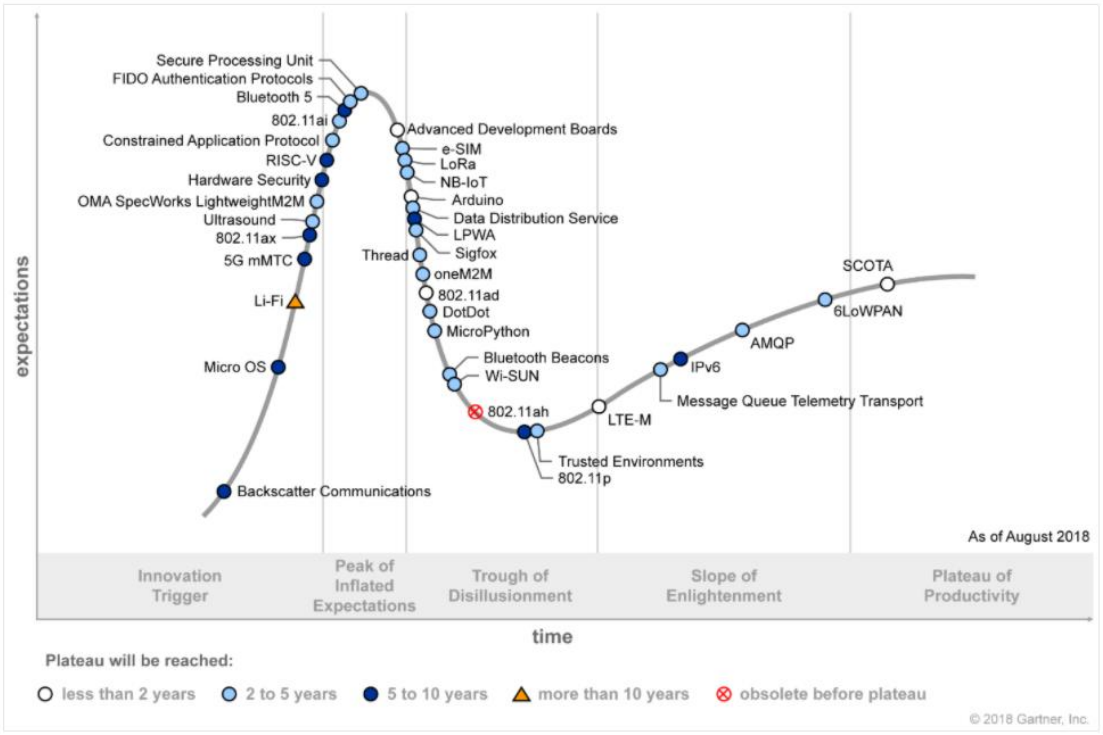

Figure 4.9: Hype Cycle for IoT Standards and Protocols 2018.

As can be seen in the figure above (Figure 4.9), Gartner places in its 2018 report on IoT Standards and Protocols, Bluetooth 5 in the Peak of inflated Expectations phase. Which for them means that the expectations of this innovative technology rise above the current reality of its capabilities.

The following is the report that Gartner produced in the same year on IoT. And as you can see (Figure 4.10), the IoT Services, which is where RTLS would be included, is located, as in the previous report, in the Peak of Inflated Expectations phase. It is also necessary to clarify that the indoor positioning shown in the slope of Enlightenment phase is located there precisely because it is not considered in real time.

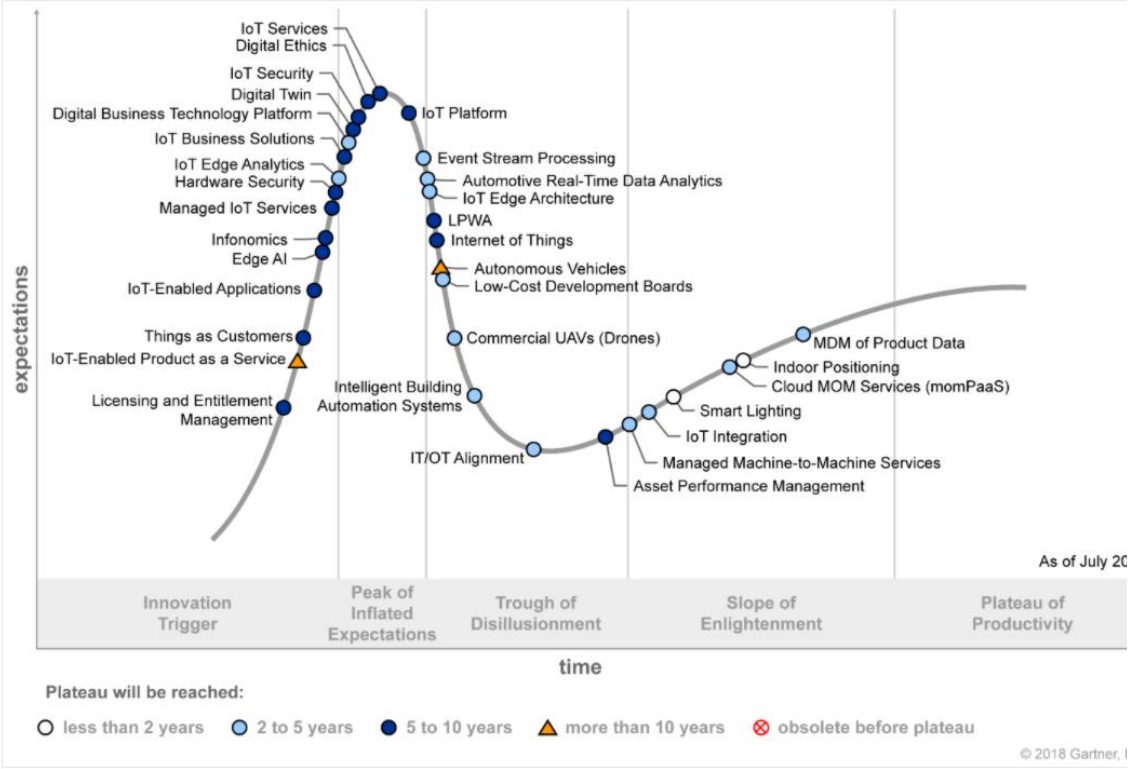

Figure 4.10: Hype Cycle for the Internet of Things 2018.

As can be seen in the two previous images, both Bluetooth 5 and IoT services are marked with a blue round, which means that the forecast that Gartner offers on when these technologies will reach the Plateau is 5 to 10 years.

This year 2020 a summary of the Hype Cycle for IoT Standards and Protocols has come to light. Of which there is no published image of the graph, but if they have made public at what point the Bluetooth 5.1 technology would be located. [35]

According to the report, Bluetooth 5.1 is located in Sliding into the Trough, which would be the area between the Peak of Inflated Expectations phase and the Trough of Disillusionment area. This means that in the two years of difference between the 2018 and 2020 report, technology has advanced on the curve in less

than one phase. Taking into account that in the 2018 report Bluetooth 5 is mentioned and in the 2020 report, Bluetooth 5.1.

The conclusion that can be drawn from the three Gartner Hype Cycle reports mentioned in relation to the technology used in our project is that the technology is at a point in which the development of the service or project that uses it must be fast since otherwise interest in it will begin to wane. Which doesn't have to mean that there is a drop in overall adoption numbers as an innovation slides toward the bottom. Rather, what vendors and investors expected to be "hockey stick" adoption remains a slow growth path. As a result, vendor consolidation and failure occur because there is too little adoption growth to support so many similar products.

4.2 Business idea structure

In the next two sections (4.2.1 and 4.2.2) the two of the most structural issues of the business idea structure will be dealt with: the revenue model and the sales and distribution model.

4.2.1 Revenue model

The revenue model is based on two main paths: production model and leasing model.

In the case of the production model it will consist of the purchase by the customer of the complete system and its installation. In addition, the buyer could qualify for a monthly system maintenance fee.

On the other hand, before explaining the leasing model, the leasing contract will be explained. The leasing contract is a contract by means of which the lessor transfers the right to use a good in exchange for the payment of rental rents for a specified period, at the end of which, the lessee has the option of purchasing the leased property by paying a determined price, return it or renew the contract.

Once explained what leasing is, it is deduced how this type of model applied to our business idea would be. It would consist of a monthly fee payment contract for a certain time in which both installation and maintenance would enter during that time. And once the contract ends, it would be decided whether to continue in the form of a lease, pay for the ownership of the system or return it.

From the buyer's point of view, the first model requires a larger investment at the beginning but in total the price is cheaper than with leasing, which allows you to have a much smaller investment at the beginning. On other matters, the leasing method can provide more flexibility and adaptability to customer needs, in addition to not having as much investment risk, although it is true that in global terms it is a more expensive model.

4.2.2 Sales and distribution model

The sales and distribution model that best suits our business idea is the Business to Business (B2B), since our goal is to sell the RLTS system with Bluetooth direction finding to companies rather than directly to customers.

The factors that B2B sales have in common are that they generally have higher order values, longer sales cycles, and are often more complex than Business to Consumer (B2C) sales.

There are three types of B2B business models, which are: Supply sales, Wholesale / distribution sales and Service / Software sales. The business idea we are considering would belong to type 3, Service sales.

Service sales are based on the sale of a service instead of a product. And it is just what we want to capture with this business idea, selling an indoor RTLS service for logistics centres or warehouses that provides improvements to the systems currently in place.

4.3 Business idea development

The business idea is to sell an RTLS system based on Bluetooth direction finding technology to companies with an important logistics department. This system will provide the purchasing company with improvements in the optimization of processes and decision-making. In addition to adding a higher degree of technological status to the company, which can be reflected as a company prepared for the future and thus be able to attract more clients or investors.

In this section the business idea will be developed with the help of different tools such as value proposition canvas, Porter's five forces, 4 actions framework, etc. Besides to conducting an in-depth analysis of the positioning and targeting that the business idea must follow. [14]

4.3.1 4 actions framework

The 4 Actions Framework [15] is a strategic tool developed by W. Chan Kim and Renée Mauborgne used in order to reconstruct elements of buyer value by developing a new value curve. Aiming to break the trade-off between the low cost of creating a new value curve and differentiation, the Framework raises four key points to challenge the strategic logic of the industry. These four key points are: eliminate, raise, reduce and create.

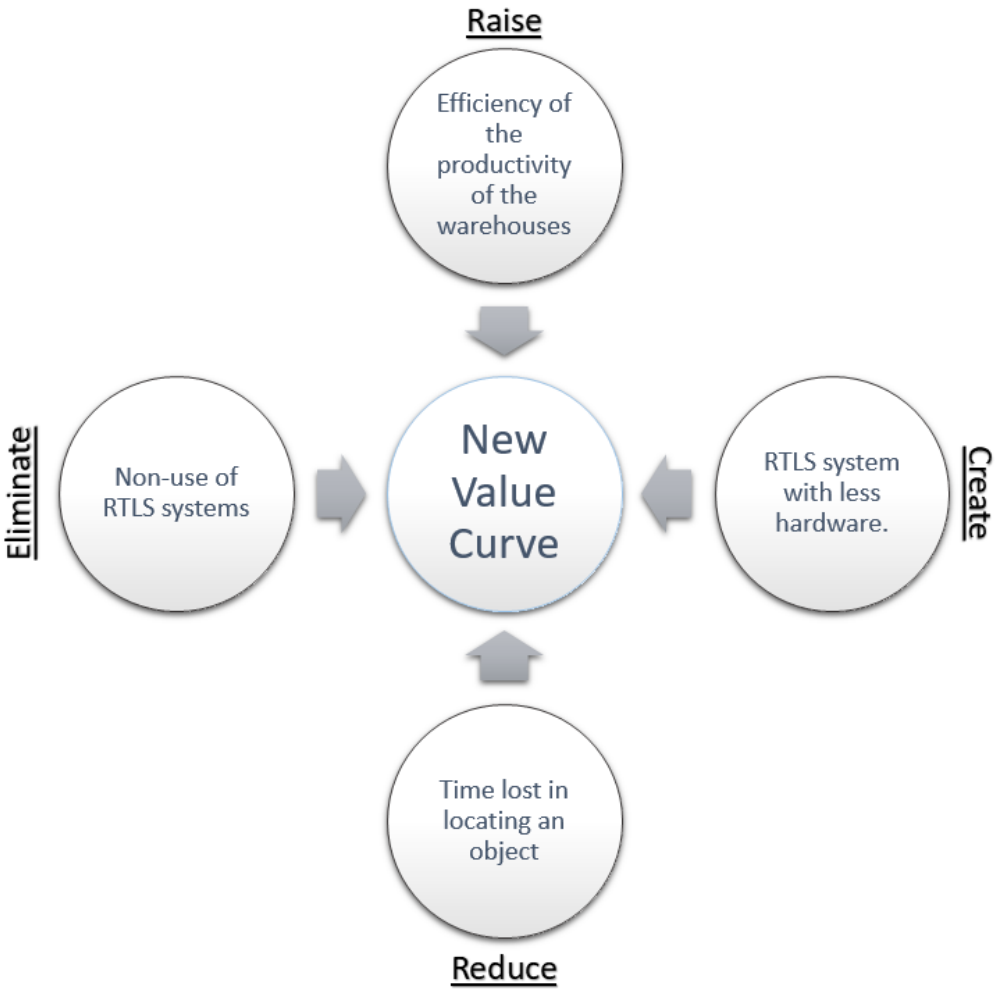

Figure 4.11: 4 actions framework diagram.

As can be seen from the diagram above (Figure 4.11), each key point encompasses a key question to solve. The question that relates to each point is detailed below.

4.3.1.1 Eliminate

The elimination point refers to which factors the industry has competed on for a long time should be eliminated. And in the case of our business idea is to eliminate the non-use of RTLS systems in warehouses or logistics centres that can cause loss of time and worsening processes.

4.3.1.2 Raise

This raise key point refers to what factors need to be raised well above the current industry standard. What in the case of the type of business idea that we are proposing, is the speed of decision making and process optimization. In conclusion the efficiency of the productivity of the warehouses.

4.3.1.3 Reduce

At this key point, as opposed to the previous one (Raise), it refers to which factors should be reduced well below the current industry standard. Which in the case of our business idea are the difficulties to find an object and the loss of time that it entails.

4.3.1.4 Create

The last key point is Create, and this refers to factors that must be created and that the industry has never offered. And as regards the case of our business idea, we want to create the possibility of implementing an interior RTLS system with the ability to know the object's position without the need for excessive hardware implementation and all thanks to the innovative Bluetooth Direction Finding technology.

4.3.2 Value proposition Canvas

The Value Proposition Canvas is a tool created and developed by Dr Alexander Osterwalder whose main objective is to ensure that a product or service is positioned around what the customer values and needs. It is a tool that helps to analyse in detail the relationship between the value proposition, customer segments and possible substitutes. [16]

The use of this tool is recommended for when developing a business idea from scratch or to readjust an existing business idea.

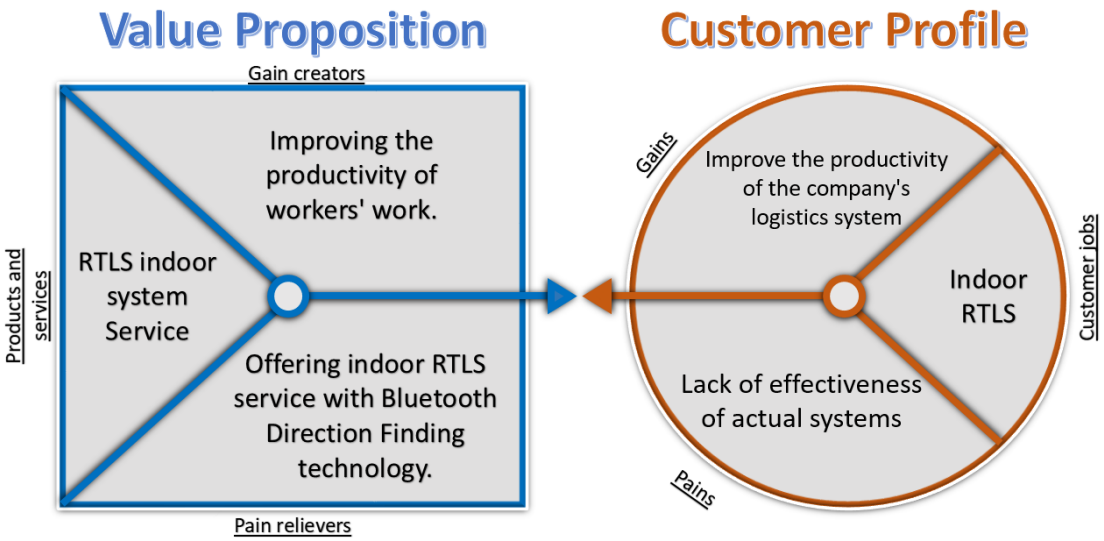

Figure 4.12: Value proposition Canvas.

In the previous figure (Figure 4.12), you can see the template that is used in the Value Proposition Canvas, where it can be seen that it is divided into two main

parts: value proposition and customer profile. Besides, in the following subsections, each of the elements of the template will be detailed and analysed with the business idea of this project.

4.3.2.1 Customer profile

The template proposes to define the following elements for each customer segment: customer jobs, pains and gains.

- Customer jobs: activities related to your product or service that customers regularly try to carry out.
- Pains: unwanted situations or costs that customers experience when performing the activities mentioned above.
- Gains: benefits that clients expect to obtain from the activities mentioned previously.

It is time to reflect the customer profile regarding our business idea. From the point of view of customer jobs, the customer seeks a service that provides indoor RTLS. The pains can be the lack of effectiveness, precision or optimization of already implanted systems. And finally, referring to the gains that the client expects to obtain, they can be time savings, process optimization. In other words, basically, improve the productivity of the company's logistics system.

4.3.2.2 Value proposition

Focusing on the value of the product, as can be seen in the template, there are three different fields: gain creators, pain relievers and products and services. The mission of this section of the proposition is to define the characteristics of the product or solution and identify which of these are solving the customer's problem.

- Products and services: products or services that you offer to your clients to help them with the activities outlined.
- Pain relievers: How do you solve the client's problems indicated in the previous section Pain.
- Gain creators: How you are bringing benefits to your customers based on the expectations of your customers mentioned above.

From the point of view of value proposition, the business idea of this project can provide the client with a very accurate and efficient indoor RTLS service, as well as being compatible with a large number of devices since it uses Bluetooth technology. And taking into account the great competitive advantage that it offers, which is the reduction of the hardware to be installed. It is important to mention that the service can offer the possibility of relating the data or metrics tracked by the system to the company's ERP system.

4.3.3 Business model Canvas

The Business Model Canvas is a tool created and developed by Dr Alexander Osterwalder and Yves Pigneur whose main objective is to define and create innovative business models by simplifying it in four major different areas: clients, supply, infrastructure and economic viability.

Below you can see the template (Figure 4.13) used to create the Business Model Canvas which is divided into nine sections with the characteristics of the company you want to create. [14]

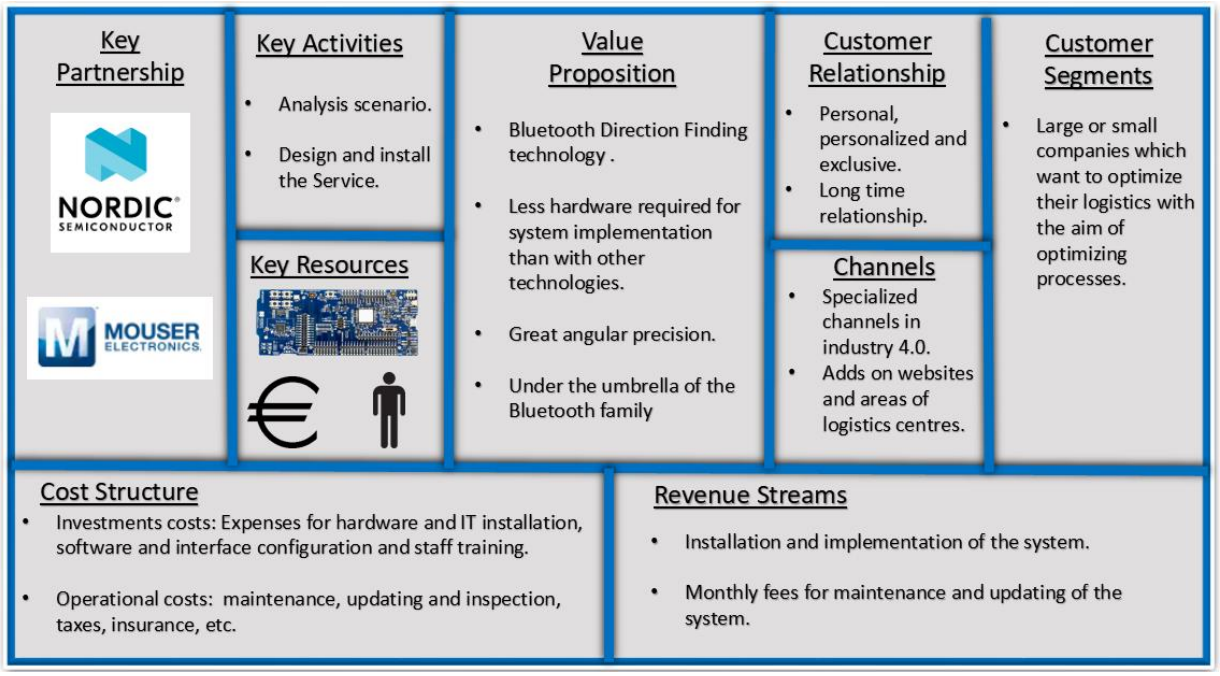

Figure 4.13: Business model Canvas.

In the following sections, each of the nine sections of the Business Model Canvas will be detailed and will be correlated with our business idea.

4.3.3.1 Customer Segments

The objective of this section is to clarify the type of client to whom this business idea is directed. It is very important to define the type of clients, because the business model and even the product may vary depending on them.

Segmentation is the act of dissecting the market into small sub-markets which require different marketing mixes. While targeting is the process of reviewing each market segment and deciding which one or which to pursue.

The reason why it is necessary to carry out the analysis of customer segmentation and target segmentation is to obtain the highest possible efficiency from the budget dedicated to business marketing. By identifying the best

customers, you can more effectively focus on the means to reach them and the best messages to capture their interest.

There are different methods to carry out customer segmentation based on the identification of customers according to different characteristics such as demographic, geographic, psychographic or behavioural / attitudinal.

In the case of our business, the most useful and effective methods are geographic and attitudinal. From a geographical point of view, segmentation can focus on clients that are located in highly industrialized areas and where there are large logistics centres. On the other hand, the attitudinal method is useful to identify clients who want to show a superior technological image, that is, to show an image of modernity.

Referring now to target segmentation, there are three types of strategies to apply it: undifferentiated, multisegment (Differentiated) and concentration (Niche) [14] [37]. And as previously discussed, our business would be found in the niche of logistics centres, warehouses and industrial areas which want to optimize their logistics with the aim of optimizing processes.

4.3.3.2 Value Proposition

The value proposition is based on your differential point against your competition. That is, why the client is going to buy from you and not from a rival of the competition.

Without a doubt, the most important added value that our innovative service offers compared to the competition is that thanks to the Bluetooth Direction Finding technology used, the hardware necessary to install is less than in any other RTLS technology.

In addition to being a Direction finding system with great angular precision and with the reliability of being under the umbrella of the Bluetooth family, what it means that is compatible with most mobile devices, in the event that a link with the system is necessary.

4.3.3.3 Channels

Channels are defined as the different ways through which the customer comes into contact with the business and becomes part of the business sales cycle.

The channels used to distribute our product and be able to reach more customers must be specialized channels in industry 4.0 or new technologies, additionally to investing in advertising on websites and areas of warehouses or logistics centres. The greatest asset to attract new customers is to show the improvements that have been obtained by customers who have already joined our service.

4.3.3.4 Customer Relationship

This section defines the way of interaction in the relationship with the client. It is necessary to differentiate if the client requires a personalized and exclusive treatment, a more personal or more automated relationship. This relationship must be in accordance with the message that the brand transmits.

Regarding the relationship with customers, our business must maintain a personal, personalized and exclusive relationship since each customer will have different needs to be covered, which means that the relationship cannot be automated.

On the other hand, the fact that the service affects the client at the physical and visual level of the structure, it is necessary to agree with him on how and where to do the installation. Besides to all this, the fact of offering the maintenance of the service means having to maintain the relationship with the client for a long time.

4.3.3.5 Revenue Streams

The revenue streams section indicates how the business converts the value proposition into financial gains. The source of income must allow the company to be profitable, but always thinking that it has to be in accordance with what the consumer asks for.

As previously mentioned in the revenue model section of the thesis, revenue streams come basically from two paths: the first is from the installation and implementation of the system and the second from the monthly fees for maintenance and updating of the system.

4.3.3.6 Key Resources

The key resources are those physical, intellectual, human or financial resources necessary for the operation of the business model, in addition to making possible the possibility of achieving the key activities.

From the point of view of raw materials, it will be necessary in addition to having the necessary technological resources such as Bluetooth 5.1 beacons and receivers (including antenna arrays), tools or security devices to proceed with the installation such as Ethernet cables, crimpers, etc. Furthermore, as is logical, our business from the point of view of human operation, it will be necessary to have experts both in the matter of Bluetooth operation and in its implementation in scenarios. In addition to personnel to operate in the field, both for installation and maintenance.

Finally, another of the key resources is the capital to pay in advance and thus be able to face and complete the purchase orders of the clients.

4.3.3.7 Key Activities

The key activities section tries to indicate the necessary actions that the business must take to achieve the value proposition to the client.

Regarding our project, the key activities are several: the first would be the requirement of an analysis of the client's scenario to verify that the Bluetooth direction finding technology is adequate. In a second step would be the design of the system and its application and installation. And finally, create the link of the data tracked to the company's ERP.

4.3.3.8 Key Partnerships

The key partnership section tries to indicate which will be your strategic alliances in order to obtain the necessary resources to carry out the project.

In the case of our project, the key alliances would be the providers of the Bluetooth chipsets necessary to implement the system. As mentioned in previous sections, Nordic Semiconductor is the main supplier with which it has been treated, although there are others such as Silicon Labs.

It is worth mentioning that in Spain, Nordic Semiconductor distributes its products through two companies: Digi-Key electronics and Mouser electronics. This means that the commercial relationship should be between these distributors and not directly with Nordic Semiconductors.

4.3.3.9 Cost Structure

The cost structure is defined as the cost of operating as a business and all the costs that this implies, such as: legal costs, insurance, etc. Structural cost can be divided into two types of cost: investments costs and operating costs.

The investments costs would be formed by expenses such as:

- Expenses for hardware and IT installation (Bluetooth chipsets and Bluetooth switchboards).
- Software and interface configuration.
- Staff training.

Operational costs would be expenses for maintenance, updating and inspection. Besides to typical business expenses such as taxes, insurance, etc.

4.3.4 Positioning

Positioning refers to the place that a company occupies in the minds of customers with respect to the competition. To demonstrate the place that our company occupies, a perceptual mapping can be used. Although it is also necessary to carry out an analysis of the differences of our company and it is what will be developed in the following subsections. [14]

4.3.4.1 Perceptual mapping

Perceptual mapping consists of a spatial image of how consumers view products or brands within the market. It also allows marketing specialists to determine how your product appears relative to competitive brands.

The figure that can be seen below (Figure 4.14) shows the perceptual mapping of the technology that our business uses, Bluetooth Low Energy Direction finding, in contrast to the technology of the competition. As you can see our technology your sample at a very balanced point between the price and the level of technology.

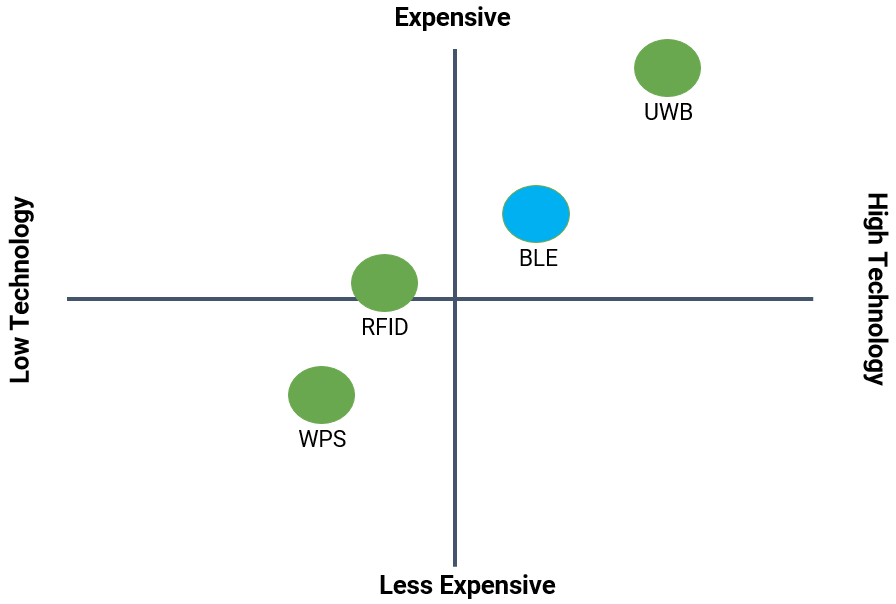

Figure 4.14: Perceptual Map: Cost vs Level of technology.

4.3.4.2 Differentiation

Differentiation consists of identifying a set of possible competitive advantages to build a position by providing a superior value from: product differentiation, service differentiation, channels, people and image.

As has been commented throughout the thesis, the differentiation of our business can reside in two points. One of them would be the advantages that it brings to the technological level to use the technology that we propose. The other point of

differentiation lies in the flexibility with the method of payment of the product, the fact of offering a leasing method can be very differential since it is not something very usual in this type of business.

4.3.4.3 Real market competition

In order to be able to analyse the state of the real competition of companies dedicated to offering RTLS and IPS services, a national market study has been carried out. This study has resulted in a total of five companies that can be placed as direct competition to the service that has been proposed to offer in this project, these five companies are: ESBSistemas, Eliko, Siemens, Infsoft and Sewio. Following, the solution provided by each of these companies will be analysed to conclude with a comparison with our solution and to be able to perform a competitive positioning in a perceptual mapping.

- ESBSistemas [18]: This company offers an RTLS solution based solely on RFID technology, which allows to automatically identify and track the location of assets or people in real time. Tags are attached to assets or carried by people for their location. In addition, it generates warnings / alarms based on the entry / exit of a certain element in a certain area. In addition, this company offers an optional platform that acts as a middleware between the supplied RFID equipment and the corporate information systems ERP.

- Eliko [19]: This company offers an RTLS (KIO) system whose main value is high precision. KIO is capable of tracking an object with a precision of 5 to 30 cm, this is because the system uses UWB technology. They also provide software to configure and manage all the elements of the system.

- Siemens [20]: Siemens offers an RTLS service based on the SIMATIC RTLS system. SIMATIC is a scalable location system specifically designed for industrial applications. The system is based on UWB technology and, thanks to the proprietary software provided, enables both employee safety in a production environment and lean manufacturing processes.

- Infsoft [21]: Infsoft is a company that provides turnkey B2B solutions for facility digitization and process automation in a wide range of industries. A point of differential of this company is that it not only works indoors, but also outdoors and also with different technologies such as Bluetooth Beacons, UWB or WPS.

- Sewio [22]: Sewio company offers an RTLS system dedicated to intralogistics, retail and livestock industries. The latter being a great differential point within the competition. The Sewio system is built on UWB technology and ships with RTLS Studio, which is remote management and viewing software. Sewio is a great company as its customers include: Volkswagen, Toyota, Budweiser Budvar, TPCA, Škoda, ENEL.

Once the analysis of the five main competencies on RTLS and IPS at the national level, the following conclusions can be drawn:

- In these times, the most widely implemented technology in the use of RTLS and IPS are those based on UWB.

- Another of the conclusions is that all the companies that offer this type of RTLS service provide a management of the data obtained, either through their own software platform or by linking with the company's ERP directly.

4.3.5 Porter's five forces

The analysis of Porter's five forces is a framework developed by Michael Eugene Porter in 1979, and whose main objective is to analyse the level of competition within the industry and the development of business strategies.

This analysis, thanks to the articulation of the 5 forces, determines the intensity of competition and rivalry in an industry, and therefore, how attractive this industry is in relation to investment opportunities and profitability. [14]

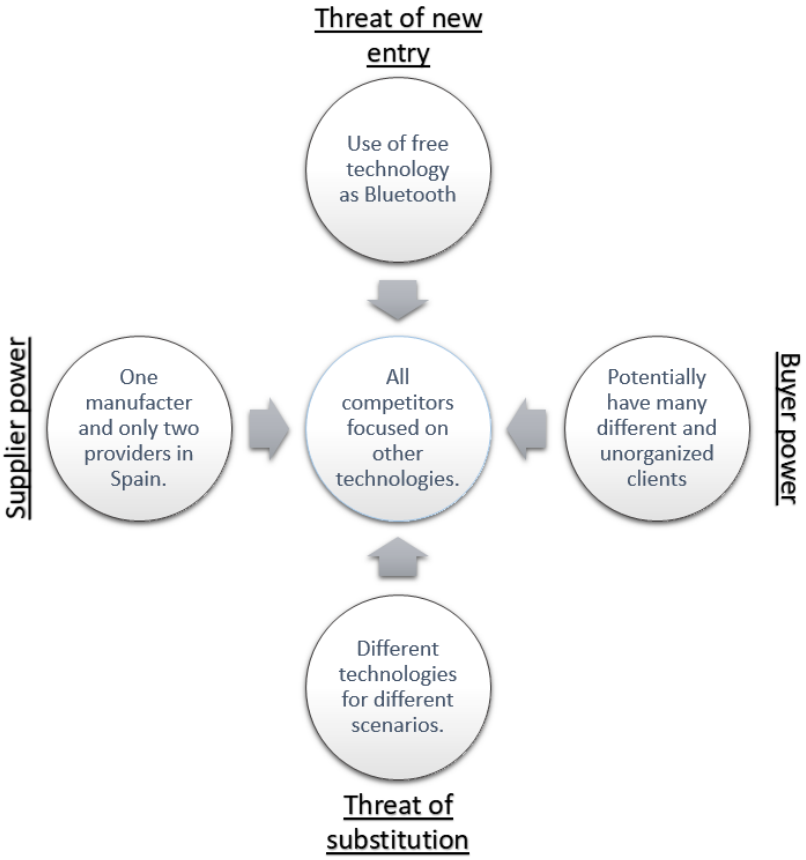

Figure 4.15: Porter's five forces diagram.

Within Porter's five forces, which can be seen in the diagram above (Figure 4.15), two types of competencies can be established: horizontal competition and horizontal competition. As horizontal competition we would have threat of new entry, competitive rivalries and threat of substitution. On the other hand, as vertical competition we would have supplier power and buyer power.

The following subsections detail each of the forces and their application to our business model.

4.3.5.1 Threat of new entry

This strength refers to the barriers to entry that new competitors encounter. A low barrier to entry means that it is very easy to enter and therefore a greater threat from new competitors.

Extrapolating to our business model, entry barriers in the world of RTLS and indoor positioning can be the capital investment necessary at the beginning both to buy the technology necessary to have stock, and, above all, to the necessary marketing to attract customers. In addition, the fact that there are limited technologies that offer RTLS also limits the possibility of competition.

The fact that a free technology such as Bluetooth is used means that it can be developed by any other company, which consequently implies a great possibility of the entry of new competitors.

It is necessary to take into account that the fact that companies as large as those mentioned in the real market competition section (4.3.5.3), although they do not currently work with this technology, do have a great capacity to enter strongly into the market as they have created a very strong business structure with a lot of investment capacity.

4.3.5.2 Threat of substitution

This force determines the possibility of the existence of substitutes capable of replacing the product of our company and representing a competent alternative. The threat of substitutes is generally greater when the value of a product is not relevant, that is, if the price and characteristics of the product are not unique. As more substitutes appear, both demand and price for products becomes more elastic.

The fear of substituting our service for another is important, because when there are different technologies, such as active RFID, UWB or WPS; it causes that perhaps ours does not supplant with guarantees the priorities of some client and for that reason it decides to change.

4.3.5.3 Supplier power

This force measures the facility that the supplier of the technology or the raw material of our company has to vary prices, delivery times, quality standard and payment methods. The smaller the supplier base, the less negotiating power our company will have.

In the case of our Bluetooth direction finding technology, the power of the provider is great since, in the case of Spain, there are only two providers and both are provided by the same manufacturer that is Nordic Semiconductor.

4.3.5.4 Buyer power

As discussed with the strength of the suppliers, the strength of the buyers is also based on the quantity and organization of the customers. If the number of clients is small or they are very well organized, clients may be able to agree to put pressure on our company with the prices they are willing to pay. In addition, this power also increases if the buyer has many alternatives to the product offered by our company since they can threaten to abandon the business relationship with us for another competitor company.

Referring to our business model, the power of the buyer is limited since we can potentially have many different and unorganized clients, since it is not something that is typical among companies that have warehouses. If it is worth mentioning, that in cases of large logistics centres that can be organized to demand a reduction in prices or rates, but it is not usual.

4.3.5.5 Competitive Rivalries

This factor is the result of the previous four and is the one that provides the organization with the information necessary to establish its market positioning strategies. Rivalry defines the profitability of a sector: the fewer competitors that are in a sector, it will usually be more profitable economically and vice versa.

It is true that in the world of RTLS and indoor positioning, there may be different rivals with technologies that offer similar solutions (RFID, UWB, WPS), which in general needs can be an important competition. This is where the value of our business idea comes in and where our strengths must be strengthened, both technologically and financially, to convince more customers and to overcome high competition within the sector.

Currently, all competition is almost entirely focused on UWB-based systems and that is why our service has a differential point over the others, since it provides competitive advantages such as those mentioned in section 4.1.3.

4.3.6 Bullseye Framework

An essential point for the business to succeed is the way in which you advertise, that is, marketing. And within this, knowing which channels to use to advertise so that the company gains attraction is very important. In order to know which marketing channels are the most appropriate for this business idea, the Bullseye Framework will be used. Which, as explained below, helps to determine which the marketing channels that must be prioritized are, since especially in start-up companies that do not have the budget of large companies to do marketing, they must select very well the marketing channels looking for the most efficient and productive.

The bullseye framework is a method that offers help to prioritize over the marketing channels that will make the company gain traction. This method was created by Gabriel Weinberg and Justin Mares in their book Traction and its premise is that when a company starts from scratch, in most cases, it does not have a very high marketing budget. And therefore, a scientific method for marketing experimentation is necessary in order to prioritize those channels that have the greatest potential. [17] [14]

The Bullseye Framework identifies 19 (Table 4.3) marketing and distribution channels through which our start-up can obtain attraction. These channels are:

Targeting Blogs	Publicity
Unconventional PR	Search Engine Marketing
Social and Display Ads	Offline Ads
Search Engine Optimization	Content Marketing
Email Marketing	Viral Marketing
Engineering as Marketing	Business Development
Sales	Affiliate Programs
Existing Platforms	Trade Shows
Offline Events	Speaking Engagements
Community Building	

Table 4.3: Marketing and distribution channels.

Each of the channels shown in the table is capable of propelling the company through a specific stage of growth. It is worth mentioning, understanding that the marketing prioritization process is a continuous process and that it must be carried out continuously in order to avoid stagnation.

The way the Bullseye Framework works can be explained in a simplified way as a classification of the 19 channels mentioned above into three categories or rings (Figure 4.16) depending on the possibility of success that each channel can offer. The book clarifies that the top 3 channels must be selected in the central ring, the following 6 in the intermediate ring and the other channels in the outer ring.

Figure 4.16: Bullseye Framework representation.

The next two subsections will detail both the inner circle and the promising ring, which means that the channels that are not mentioned there belong to the Long-shot ring.

4.3.6.1 Inner circle

As mentioned above, this ring is made up of the top 3 channels. This means that they are the most promising channels and therefore the channels to which all efforts and resources will be applied. These channels are: search engine marketing, trade shows and search engine optimization.

As can be seen, two of the three channels are related to search engines, this is because they offer a very large potential targeting possibility, which can lead to a higher success rate. On the other hand, the third channel is Trade shows, which has been chosen because it offers the opportunity to show the product / service in person. These events are typically behind closed doors or exclusive with industry experts and insiders. Furthermore, they are designed to foster interactions between vendors and their prospects.

4.3.6.2 Promising circle

This ring is made up of the next six most promising channels, that is, the equivalent of the channels positioned from top 4 to top 9. These channels will be the first to be used once the inner circle channels have given the expected results. These six channels are as follows: offline events, community building, email marketing, targeting blogs, business development and unconventional PR.

The choice of these six channels is based on a mixture of ease of reaching different clients and the possibility of establishing a relationship of trust with the potential client. Thus, a network of contacts can be developed, enabling a flow of clients.

CONCLUSIONS

The master's thesis began developing a review of the state of the art of the Internet of Things, seeing its impact worldwide, its possible applications and the different types of technologies that are part of it.

Once this review was carried out, a study of the innovative Bluetooth Direction Finding technology was carried out, which would be used to develop an indoor RTLS service to be able to apply it to the evolution of Industry 4.0 and more specifically to its logistics.

After carrying out said study of the version of Bluetooth 5.1 and its new features that it incorporates in order to offer the capacity of direction finding, we went on to see the feasibility of the implementation of this technological idea, and this is where it is shown how a service based in this technology.

As mentioned in the memory, the development of a physical demonstration of the system's operation could not be carried out for different reasons, among which are the non-existence on the part of the supplier of the chips of a development kit that included a solution with a development board, antenna array and firmware. That is why from this point on, the remainder of the project is based on the business model that is created from the theoretical operation of technology.

Throughout the development of the business model, the current state of the market, the competitive advantages offered by this technology and even the most efficient types of scenarios for it are studied. In addition to analysing at what point the Gartner Hype Cycle report leaves the irruption of this technology, which as mentioned is not very favourable and suggests that a service that applies this technology is almost more appropriate for a company already established in the market than for a start-up. Once this analysis is carried out, the bases of the business model, its revenue, sales and distribution model are established. Opting for a B2B model and an innovative revenue model such as leasing.

After establishing the bases, the in-depth development of the business model begins. Being the analysis of the competition at the competition level an important point of the same and where it is seen that the technology on the rise in the field of RTLS is UWB. And this is where the comparison between this technology and our version of Bluetooth is made, seeing as a competitive advantage, apart from the price, the savings in hardware that using Bluetooth Direction Finding can offer.

And it is this saving of hardware, the key advantage on which development tools such as the Value Proposition Canvas, the Business Model Canvas or Porter's five forces are based. Also adding at the end, thanks to the Bullseye Framework, a point of analysis of the channels to prioritize when doing marketing.

From my point of view, the implementation of a service like the one developed in this thesis fits very well within the revolution that is currently being experienced with Industry 4.0 and even Logistics 4.0.
The service as shown during the theses, can offer great benefits over traditional logistics centres as well as a great increase in process optimization. It should also be noted that it has advantages over the technologies already used today in logistics centres with RTLS such as the UWB or WPS.

However, I think that, as mentioned in the analysis of Gartner's Hype Cycle, offering a service of this style with this technology seeing the competition so implanted that exists will not be entirely easy to carry it out with a Start-up in comparison with an already consolidated company and with its already established development structure.

Future work for this project would be the development of the physical demo of the service when the providers bring to light the necessary development kits, including from the real location of an object to its transmission to the company's ERP server.

To finish, referring to the possible sustainability considerations that may apply to this project, I believe that the fact of making the move to a more modern and intelligent Industry 4.0 directly implies a cost reduction for any company due to the optimization of resources and processes that can be achieved. And this optimization of processes and time is a plus point on the environmental impact that the change to industry 4.0 implies, since this saving of resources can directly or indirectly result in energy savings.

ACRONYMS

AoA	Angle of Arrival
AoD	Angle of Departure
B2B	Business to Business
B2C	Business to Consumer
BLE	Bluetooth Low Energy
CRC	Cyclic Redundancy Check
CTE	Constant Tone Extension
ERP	Enterprise Resource Planning
HCI	Host Controller Interface
IEEE	Institute of Electrical and Electronics Engineers
IETF	Internet Engineering Task Force
IoT	Internet of Things
IPS	Indoor Positioning Systems
IQ	In-phase and Quadrature
ITU	International Telecommunication Union
KPI	Key Performance Indicator
LLN	Lossy and Low power Networks
LoS	Line of Sight
NFC	Near-Field Communication
PDK	Process Design Kit
PDU	Protocol Data Unit
PHY	Physical
PR	Public Relations
RFID	Radio Frequency Identification
RPL	Routing Protocol for Low-Power
RTLS	Real Time Location System
SoC	System on a Chip
UCA	Uniform Circular Array
ULA	Uniform Linear Array
URA	Uniform Rectangular Array
UWB	Ultra-Wideband
WPS	Wi-Fi Positioning System

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